HIGH DEPOSITION WELDING

VOLUME 11

USE OF POWDER METAL FILLER MATERIALS FOR HIGH DEPOSITION RATE ONE- SIDE WELDING

DECEMBER 31, 1978

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
DEC 1978	**N/A**	**-**

4. TITLE AND SUBTITLE
High Deposition Welding Volume II, Use of Powder Metal Filler Materials for High Deposition Rate One - Side Welding

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128-9500 MacArthur Blvd Betheda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**50**	

FOREWORD

The purpose of this report is to present the results of one of the research and development programs which was initiated by the members of the Ship Production Committee of The Society of Naval Architects and Marine Engineers and financed largely by government funds through the cost sharing contract between the U.S. Maritime Administration and Bethlehem Steel Corporation. The effort of this project was directed to the development of improved methods and hardware applicable to shipyard welding in the U.S. shipyards.

Mr. W. C. Brayton, Bethlehem Steel Corporation, was the Program Manager. The development work was performed at TAPCO, International under the direction of Dr. G. H. Reynolds and Mr. E. J. Kachelmeier.

Special acknowledgement is made to the members of Welding Panel SP-7 of the SNAME Ship Production Committee who served as technical advisors in the preparation of inquiries and evaluation of sub-contract proposals.

EXECUTIVE SUMMARY

BACKGROUND

The use of powder metal filler materials to achieve higher deposition rates and the use of non-metallic backing materials for one-side welding have become viable production techniques. Various methods of application are being investigated to determine which processes are best suited to specific shipbuilding applications.

OBJECTIVE

Develop a machine capable of utilizing the process of automatically dispensing iron powder in a butt weld joint welded from one side with ceramic backing. The machine must be able to pass through a 10″ x 4″ opening.

ACHIEVEMENT

The objective was accomplished. A machine meeting the physical constraints was developed and demonstrated with both gasless flux core and submerged arc processes. Welds of acceptable appearance and quality have been produced under laboratory conditions and the machine is presently being field tested in a shipyard.

This type of equipment offers proven cost savings and better reliability of machine welding in confined areas where conventional equipment will not work.

ABSTRACT

An apparatus for fully automatic butt welding with metal powder filler additions in confined work spaces has been constructed and tested. Design details of the experimental apparatus are presented. Procedures have been developed for both flux-cored and submerged arc welding of ABS Grade DH32 plate. Acceptable weldment mechanical properties are obtained for both welding processes when a blended mild steel powder composition is used. The various types of weld defects which may be produced during one-side welding with metal powder fillers are discussed. Preliminary observations on stainless cladding and control of distortion in butt welding with the experimental apparatus are also presented.

INTRODUCTION

The purpose of this investigation was to develop an apparatus for fully automatic one-side welding in confined spaces using metal powder filler additions. Metal powder filler additions were used to increase the total deposition rate of the welding process employed, either flux-cored or submerged arc, thereby improving the likelihood of producing single-pass one-side welds of acceptable quality. Performance of the one-side welding operation in severely restricted work spaces during subassembly fabrication and final fit-out imposed severe size restrictions on the experimental welding apparatus. The equipment was designed to traverse a 4.0 X 10.0 in. bulkhead opening while but welding 1.0 in. plate. Development of an apparatus of this type would permit increased shipyard utilization of fully automatic one-side welding.

ALTERNATIVE CONCEPTUAL DESIGNS

After a survey of shipyard welding operations, two conceptual designs for one-side butt welding were considered. Figures 1 and 2 show schematic representations of top-side and bottom-side tractors capable of one-side welding with metal powder filler additions.

In Figure 1, several features of the top-side apparatus are shown which are required for successful operation. Due to space limitations, a metering device consisting of a segmented dispensing-wheel rotating in a horizontal plane is used to supply the metal powder filler in a preset ratio to the weight of welding electrode. The powder may then be fed to the weld in any of several ways. Powder may be dispensed directly to the electrode to be held in place by electromagnetic forces during DC operation. Alternatively, powder may be dispensed in the joint

and ahead of the welding arc as is common practice in submerged arc welding with powdered filler metal. Also, a combination of these dispensing methods may be employed whereby the metal powder is dispensed ahead of the welding arc, conveyed by an inert carrier gas stream to the welding electrode and held in place on the electrode by electromagnetic forces. In submerged arc operations, the metering device may be used to supply a mixture of metal powder and welding flux if desired. Although not shown in Figure 1, it was felt that a mechanical weld nozzle oscillator would probably be required for complete consumption of metal powder during welding.

The alternative design for a metal powder system intended to interface with bottom-side tractors being developed elsewhere is shown in Figure 2. The principal feature of this design is a ceramic “shark’s fin" guide which acts both as an electrode and metal powder guide. Metal powder is conveyed to the vicinity of the contact tip by an inert carrier gas stream. Submerged arc welding flux may be conveyed in a similar manner. The powder is fed to an air disengage (settling chamber) from which it is gravity fed to the weld. Although this design is simple from an equipment point of view, it presents difficulties with respect to the mechanics of the welding process. The principal difficulties with this configuration are the impossibility of performing multi-pass operations if required and the inability to oscillate the electrode during welding. Because of these difficulties, it was decided to concentrate on the development of the top-side apparatus.

Either equipment design may be used with flux-core or solid electrodes in the self-shielded, gas-shielded or submerged arc modes alone or in combination with metal powder filler. At the outset, it was believed that the principal limiting factor in successfully performing the one-side welding operation in a single pass

would be the ability of presently available ceramic backing materials to withstand the extreme heat input of such operations.

EVOLUTION OF ONE-SIDE WELDING APPARATUS

The first top-side welding apparatus constructed during this investigation is shown in Figure 3 in the final stages of construction. This view shows the complete tractor with the exception of the metal powder and flux hoppers. Direction of travel during welding is from right to left in Figure 3. Also from right to left in Figure 3, the essential features of the tractor are the contact tip/nozzle, wire feed mechanism, horizontal rotating metal powder dispenser, carriage drive motor and wire spool for self-contained operation. Figure 4 is an underside view of the tractor, showing the single track and toothed carriage drive gear. Figure 5 shows a more detailed top-side view of the carriage drive motor, metal powder dispensing device and the slide for positioning the powder orifice *as* required during welding. An underside view of these same components is shown in Figure 6 where the bottom of the rotating powder dispensing device can be clearly seen. Figure 7 shows the wire feed mechanism and contact tip/nozzle.

Welding trials with the original tractor as shown in Figures 3-7 pointed out a number of difficulties with the original design. It was found, for example, that a mechanical weld nozzle oscillator was definitely required for complete metal powder consumption, particularly in flux-core welding, even at fairly low ratios of metal powder to electrode wire. In addition, the original carriage drive motor was inadequate to provide smooth operation of the tractor at low travel speeds (<8.0 ipm.). Also, the pinch-roll wire feeder was unable to handle electrodes greater than 1/16 in. diameter and was unable to provide stable wire feed at high currents.

On the basis of these first welding trials, a number of refinements in the original design were made. Figure 8 shows a top-side view of the final version of the welding apparatus with the metal powder hopper removed. To correct the deficiencies encountered with the pinch-roll type wire feeder, a 0.16 Hp linear wire feeder was installed. This permitted the use of either solid or fabricated 3/32 in. diameter electrodes at welding currents up to 600A . The linear wire feeder also permitted use of a stationary wire source rather than the small capacity spool which was previously mounted on the tractor. A larger carriage drive motor was installed to improve low speed travel characteristics. Also, a crank-type mechanical oscillator was installed to facilitate complete metal powder consumption during welding. Figure 9 shows a front view of the equipment in which the oscillator can be clearly seen. Minor changes were also made in the electronic controls which were altered for ease of operation. (As shown in Fugures 8 and 9, the apparatus is powered by a 110 V AC source. The control system can be modified to operate directly from the DC welding power supply itself by means of solid state switching circuitry eliminating the need for a separate 110 V power source.)

Figure 10 shows an exploded view of the tractor in its final form. All components are shown with the exception of the wire spool, flux hopper and metal powder hopper. For submerged arc operation, a flux hopper would be mounted on the trailing end of the tractor, i.e. to the right in Figure 10. A full size plan view is shown in Figure 11 to illustrate the compactness of the arrangement of components. Control, wire feed and other permanent magnet motor wiring diagrams and schematics are shown in Figures 12-14.

One feature which was not incorporated in the apparatus as part of this program but

which should be mentioned is a seam tracking device to adjust the travel speed of the tractor in response to variations in joint width. It is felt that such a device would be relatively simple to incorporate into the tractor and may be a highly desirable feature for shipyard operation.

The equipment was used in this final configuration throughout the investigation.

WELDING PROCEDURE DEVELOPMENT

Flux-Cored Welding

Initial welding tests were conducted using the 2/16 in. diameter Lincoln NR 203 M flux-cored electrode. Table I shows welding conditions found most satisfactory for use with this electrode. The weight ratio of metal powder to electrode wire of 0.85 is somewhat lower than the ratio normally used in submerged arc welding. A total process deposition rate of 22.0 lbs/hr. (combined powder and wire) was obtained with the process parameters shown in Table I. Although certain applications may require the use of small diameter electrodes, it was felt that the total metal deposition rate was too low to warrant further study of the 1/16 in. diameter electrodes.

Table II shows the preferred welding conditions when using 3/32 in. diameter Lincoln NR 302 flux-cared electrodes. A total process deposition rate of 29.4 lbs/hr. at 475 A was observed with these larger electrodes.

One conclusion reached early in the welding tests was that the 60° included angle joint design (Tables I and II) was unnecessarily large because of the wide root openings required for the ceramic tile weld backing. For this reason, the joint design was changed to a 30° included angle. This joint configuration

was retained for the remainder of the tests.

A second series of tests with the 3/32 in. diameter flux-cored electrode was performed with the root opening varied from 0.0 - 0.5 in. with corresponding variations in other process parameters as shown in Table III. Each test plate was radiographed over the entire 24.0 in. length upon completion of welding. Results of radiographic examination are shown in Table IV. Figures 15 - 18 show a metallographic cross-section and a portion of the radiograph of each plate. With a joint design having 0.0 root opening, incomplete penetration of the joint occurred over the entire length of the weld as show-n in Figure 15. Increasing the root opening to 0.19 in. resulted in incomplete joint penetration on an intermittent basis as shown in Figure 16. At 0.25 in. root opening, adequate penetration, acceptable back bead appearance and weld metal soundness were consistently obtained as shown in. Figure 17. The appearance of the as-welded plate is shown in Figure 18 after removal of the run-on and run-off tabs. In Figure 18, the run-on tab was located to the right. The back bead shows the typical “cold start” observed when using ceramic tile backings. With the joint root opening further increased to 0.5 in. , occasional lack-of-fusion defects near the mid-plane of the plate were observed as shown in Figure 19. This is considered to be due to improper electrode positioning in the joint rather than to the large root op`ening. On the basis of these tests, it is believed that root openings at 0.25 - 0.5 inches will be satisfactorily welded in production applications. Narrower root openings are expected to be subject to incomplete penetration when welding with metal powder filler.

One plate from this series, No. 2, was subjected to destructive mechanical

testing on the basis of acceptable radiographic and cross-sectional examinations. The results of these tests were satisfactory and are summarized in Table V.

Eleven additional welding tests utilizing the Lincoln NR 302 flux-cored electrodes with metal powder filler additions at a constant weight ratio of 1.0 were also performed. The purpose of the more extensive series of tests was to examine the use of prealloyed, atomized and blended metal powder compositions identical in chemistry to the weld metal deposited by the flux-cored electrode and also the use of a blended mild steel powder composition. Table VI shows the manufacturer's chemical analyses of the flux-cored electrode and of a special heat of atomized prealloyed metal powder procured for these tests. A blended metal powder composition identical to that of the atomized powder was also prepared. The final powder type utilized was a blended mild steel composition, designated M12K, containing approximately 0.50% nickel also shown in Table VI.

Table VII gives the welding conditions used for the test plates in this series. Each plate was radiographed after welding. All were found to contain defects to some degree. The most common defects encountered were severe centerline porosity in the root pass, due to gas evolution, and wormhole porosity between the first and second passes due apparently to the same cause. The appearance of the defects found in the root pass and at the interface between the root and second passes is shown in Figure 20. It appears that both the atomized and blended powders of similar composition to the welding electrode, when used in combination with the welding electrode, produce molten metal which is extremely reactive with respect to the ceramic tile backing. In addition, in several cases, the root pass appears to have a tenacious slag adhering to it which produces a

lack of fusion between the first and second passes. It should be noted that subsequent passes using similar welding conditions did not produce similar types of defects. On this basis, it may be concluded that the extreme chemical activity noted in the root pass is due to the presence of the ceramic tile and is not inherent in the process of welding with the special metal powder compositions.

A notable improvement in root pass soundness was found when the blended mild steel M12K powder was used with the Lincoln electrode. A cross-section through a weldment of this type is shown in Figure 21. A slight amount of weld metal porosity is still observed. This porosity does not appear to be related to the presence of the ceramic tile backing which is relatively neutral to this Particular powder/wire combination. It may be recalled that this powder/wire combination produced satisfactory results at weight ratios of 0.85 and 0.3. The weight ratio of 1.0 used in these tests is too high for complete powder consumption, leading to porosity in the weld metal. With the 3/32 in. flux-cored electrode, the optimum ratio for complete powder consumption lies in the range of 0.3 - 0.85. Test plates in this series subjected to destructive mechanical testing for information purposes possessed tensile strengths in the 60-68,000 psi. range and impact strength in the range of 2 - 25 ft-lbs. at -20°C.

This series of tests indicated an important consideration in the use of ceramic backing materials. It is clear that the "neutrality" of such backing tapes is highly dependent on the weld metal composition used. It is possible that certain difficulties associated with the reactivity of the ceramic backing tape may be minimized through the proper selection of powdered filler metals. Further experimentation to determine the most effective means of utilizing metal powder

filler additions in combination with non-metallic backing materials is clearly justified.

Submerged Arc Welding

Table VIII shows submerged arc welding conditions used for the 60° and 30° included angle joint configurations. Submerged arc welding performance of the experimental tractor was found to be acceptable both with and without metal powder filler additions. Weld metal soundness in submerged arc operation was generally better than obtained in flux-cored welding. The cross-section appearance of a typical submerged arc weldment using the 30° included joint configuration with M12K powder, Lincoln L61 electrode and Lincoln 860 flux is shown in Figure 22. Excellent mechanical properties were obtained for welds of this type as summarized in Table IX. These results may be compared with the flux-cored test results shown in Table V. Note that higher ratios of metal powder to wire are used in submerged arc welding than in flux-cored welding.

Distortion Control

Figure 24 shows a comparison of the degree to which distortion may be controlled with the experimental apparatus through use of optimum welding conditions with metal powder filler and the 30° included angle joint design. The top plate was welded with submerged arc using a 60° included angle, no addition of metal powder filler and no oscillation of the welding electrode. These parameters are expected to produce the maximum degree of weldment distortion. The lower plate in the figure was welded with the flux-cored process with 30° included angle, 0.25 in. root opening, optimum ratio of metal powder filler additions and electrode oscillation. The reduction in the degree of weldment distortion is apparent.

Stainless Cladding

Two tests were made using Stoody self-shielding 309 stainless steel electrodes and a Tapco 317 blended stainless steel powder composition. Welding conditions are shown in Table X. Figure 23 shows a photograph of the cladding bead appearance observed in these tests. Chemical analysis of a second-pass cladding produced with this procedure is given in Table XI. The cladding chemistry results are considered to be encouraging for the prospects for using the experimental apparatus in surfacing operations as well as for butt and fillet welding of stainless steels. The use of self-shielding stainless electrodes in combination with metal powder filler additions is a *relatively* little publicized form of automatic welding with metal powders which has proved to be highly successful in the limited trials to date.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mr. C. L. Myers and Mr. T. L. Carter of Tapco International for their assistance in the experimental portion of this investigation and to Mrs. F. M. Reynolds of Materials Sciences Northwest for preparation of the summary report.

TABLE I

WELDING CONDITIONS - 1/16 IN. DIAMETER FLUX-CORED ELECTRODE

Plate Grade	ABS DH32
Joint Details	1.0 in. plate, single bevel, 60° included angle, 0.25 in. root opening
Backing Material	3M SJ8069X Ceramic Tile
Metal Powder	Tapco M12K
Wire	Lincoln NR 203M
Voltage	22 V DCSP
Electrode Extension	1.0 in.
Amperage	275 A (First Pass) 300 A (Second Pass - Out)
Travel Speed	6.0 ipm.
Powder/Wire Weight Ratio	0.85
Oscillation Width	0.25 in. (First and Second Pass) 0.375 in. (Out)
Oscillation Frequency	60 cpm.
Process Deposition Rate (Powder and Wire)	22.0 lbs/hr.

TABLE II

WELDING CONDITIONS - 3/32 IN. DIAMETER FLUX-CORED ELECTRODE

Plate Grade	ABS DH32
Joint Details	1.0 in. plate, single bevel, 60°included angle, 0.25 in. root opening
Backing Material	3M SJ8069X Ceramic Tile
Metal Powder	Tapco M12K
Wire	Lincoln NR 302
Voltage	34 V DCRP
Electrode Extension	1.0 in.
Amperage	475 A (First Pass - Out)
Travel Speed	8.0 ipm.
Powder/Wire Weight Ratio	0.85
Oscillation Width	0.25 in. (First Pass - Out)
Oscillation Frequency	60 cpm.
Process Deposition Rate	29.4 lbs/hr.

TABLE III

WELDING CONDITIONS -3/32 IN. DIAMETER FLUX-CORED ELECTRODE

CONSTANTS

Plate Grade	ABS DH32
Joint Design	1.0 in. plate, single-bevel, 30° included angle
Backing Material	3M SJ 8069X Ceramic Tile
Metal Powder	Tapco M12K
Wire	Lincoln NR 302
Voltage	34 V DCRP
Electrode Extension	0.875 in.
Amperage	500 A
Powder/Wire Weight Ratio	0.3
Process Deposition Rate	21.7 lbs/hr.

VARIABLES

Test No.	1	2	3	4
Root Opening (in.)	0.19	0.25	0.50	0.0
Travel Speed (ipm.)	10	10	6.5	12
Oscillation Frequency (cpm.)	50	50	72	50
Oscillation Width (in.)	0.25	0.25	0.875	0.0
No. Passes	4	5	4	4

TABLE IV

X-RAY RESULTS - TEST PLATES 1 - 4
(Welding Conditions Given in Table III)

Test No.	1	2	3	4
Comments	Insufficient penetration-intermittent.	Satisfactory	Occasional lack of fusion-mid plane of plate.	Insufficient penetration-entire length of weld.
Reference Figure	16	17	19	15

TABLE V

WELDMENT MECHANICAL PROPERTIES - FLUX-CORED PROCESS WITH POWDER ADDITIONS

(Test Plate No.2, As-Welded)

Traverse Tensile Strength (psi.)	80,300*/81,100** *Fracture Location - Base Metal **Fracture Location - Weld Metal	
Guided Bend Tests	Four (4) Tests - Satisfactory	
CVN Impact Tests @ -20°C (ft-lbs.)		
Weld Metal	32/27/29	Average 29.3
HAZ	34/25/26	Average 28.3

TABLE VI

FILLER METAL CHEMICAL ANALYSIS (WEIGHT %)

Element	Flux-Cored Wire* (Lincoln NR-302)	Atomized Powder**	M12K Powder***
Al	0.72	0.31	0.05
C	0.093	0.038	0.120
Cr	0.02	0.18	0.00
Fe	Bal.	Bal.	Bal.
Mn	0.90	1.21	1.20
Mo	0.02	0.03	0.00
Ni	0.01	0.07	0.50
Si	0.22	0.27	0.55
V	0.01	0.02	0.00

* Typical analysis, supplied by Lincoln Electric Company, Cleveland, Ohio.

** Lot analysis, supplied by Metallurgical "International, New Shrewsbury, New Jersey.

*** Typical analysis, supplied by Tapco International, Houston, Texas.

TABLE VII

WELDING CONDITIONS - 3/32 IN. DIAMETER FLUX-CORED ELECTRODE

CONSTANTS

Plate Grade	ABS DH32
Joint Design	1.0 in. plate, single bevel, 30° included angle
Backing Material	3M SJ 8069X Ceramic Tile
Voltage	33 V DCRP
Amperage	475 A
Electrode Extension	1.0 in.
Oscillation Frequency	52 cpm.
Powder/Wire Weight Ratio	1.0
Process Deposition Rate	31.8 lbs/hr.

VARIABLES

Test Number	5	6	7	8	9	10	10A	11	12	12A	14
Root Opening (in.)	0.25	0.25	0.375	0.5	0.25	0.25	0.375	0.375	0.375	0.375	0.25
No. Passes	4	4	4	4	3	2	3	4	4	3	3
Travel Speed For Successive Passes (ipm.)	8.0 6.75 6.5 4.0	8.0 6.75 6.5 4.0	6.0 4.75 5.5 3.0	6.0 4.75 5.5 3.0	7.25 6.0 2.5	5.25 3.0	5.75 3.5 2.5	6.0 4.75 5.5 3.0	6.0 4.75 5.5 3.0	5.75 3.5 2.5	.6 6.5 3.25
Oscillation Width For Successive Passes (in.)	0.25 0.375 0.5 0.625	0.25 0.375 0.5 0.625	0.25 0.50 0.625 0.75	0.25 0.50 0.625 0,75	0.25 0.375 0.625	0.25 0.50	0.25 0.50 0.75	0.25 0.50 0.625 0.75	0.25 0.50 0.625 0.75	0.25 0.50 0.75	0.25 0.375 0.625
Filler Metal Type*	M12K	B	B	A	B	A	A	A	A	M12K	B

*M12K = Blended Mild Steel Composition Shown in Table VI

A = Atomized Composition Shown in Table VI
B = Blended Composition Similar to A

TABLE VIII

WELDING CONDITIONS - 3/32 IN. DIAMETER ELECTRODE - SUBMERGED ARC PROCESS

CONSTANTS

Plate Grade	ABS DH32
Plate Thickness	1.0 in.
Root Opening	0.25 in.
Backing Material	3M SJ 8069X Ceramic Tile
Metal Powder	Tapco M12K
Wire	Lincoln L-61
Flux	Lincoln 860
Electrode Extension	1.0 in.

VARIABLES

	NO POWDER	POWDER (1.0 Ratio)
Joint Included Angle,(°)	60	30
Voltage, V (DCRP)	37	36
Amperage, A	400	425
Travel Speed (ipm.)	15	12.0
Oscillation Width (in.)	0	0.25
Oscillation Frequency (cpm.)	0	52
No. Passes	15	4
Process Deposition Rate (lbs/hr.)	10.0	21.0

TABLE IX

WELDMENT MECHANICAL PROPERTIES - SUBMERGED ARC PROCESS WITH POWDER ADDITIONS
(As-Welded)

Traverse Tensile Strength (psi.)	77,900*/77,400* *Fracture Location - Weld Metal
Guided Bend Tests	Four (4) Tests - Satisfactory
CVN Impact Tests @ -20°C (ft-lbs.) Weld Metal	56/35/35 Average 42.0

TABLE X

WELDING CONDITIONS - 3/32 IN. DIAMETER - FLUX-CORED ELECTRODE -STAINLESS STEEL

Base Plate	ABS DH32
Metal Powder	Tapco 317
Wire	Stoody 309 Self-Shielding Open-Arc
Voltage	34 V DCRP
Amperage	425 A
Travel Speed	7.0 ipm.
Powder/Wire Weight Ratio	0.5
Oscillation Width	1.125 in.
Oscillation Frequency	60 cpm.

TABLE XI

CHEMICAL ANALYSIS - STAINLESS CLADDING (SECOND PASS)

Element	Weight %
C	0.020
Cr.	19.92
Fe	Bal .
Mn	1.36
Mo	0.59
Ni	11.36
Si	0.47

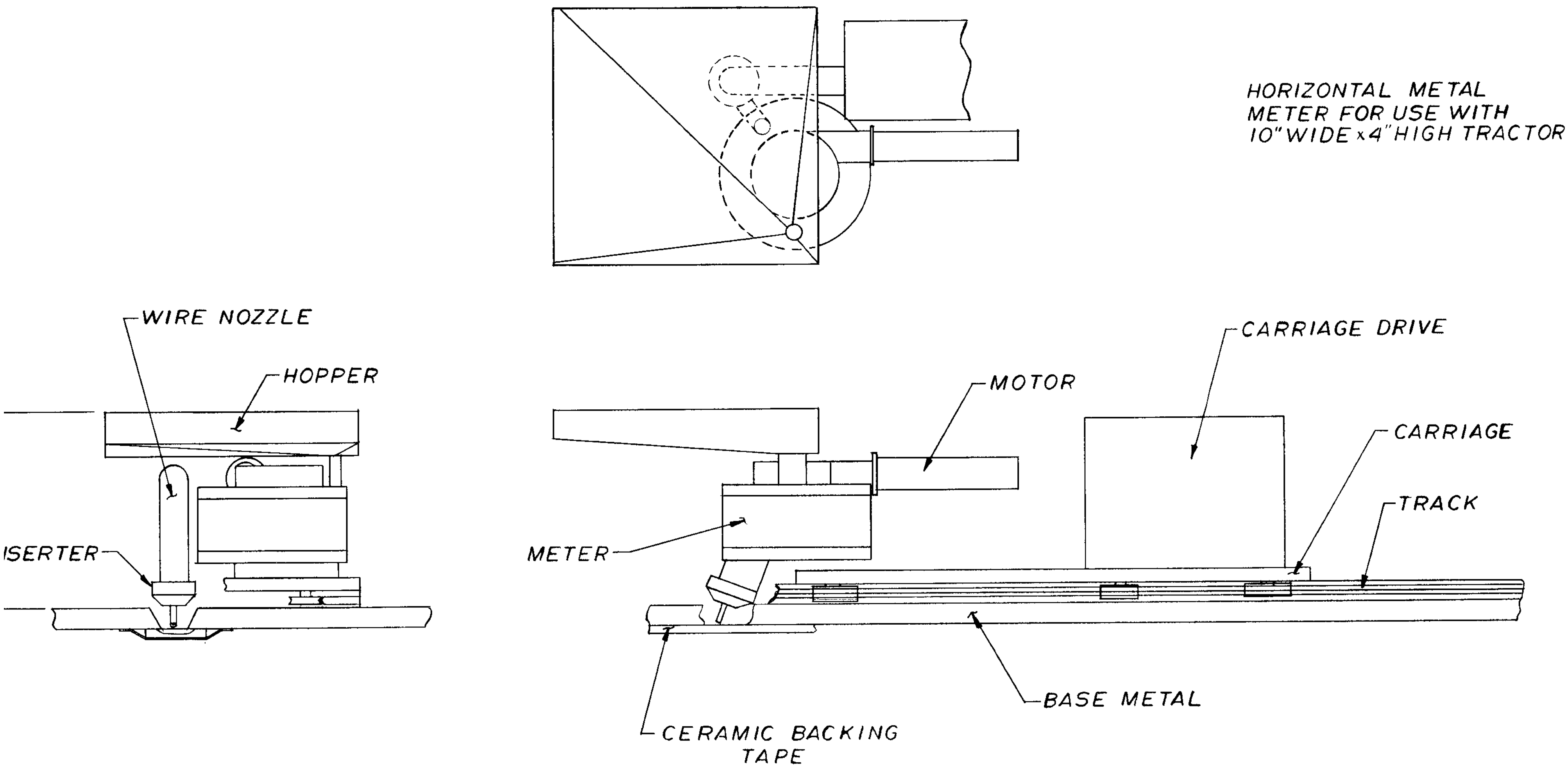

HORIZONTAL METAL
METER FOR USE WITH
10" WIDE x 4" HIGH TRACTOR
WIRE NOZZLE
HOPPER
ISERTER
CARRIAGE DRIVE
MOTOR
CARRIAGE
TRACK
METER
BASE METAL
CERAMIC BACKING
TAPE

FIGURE 1

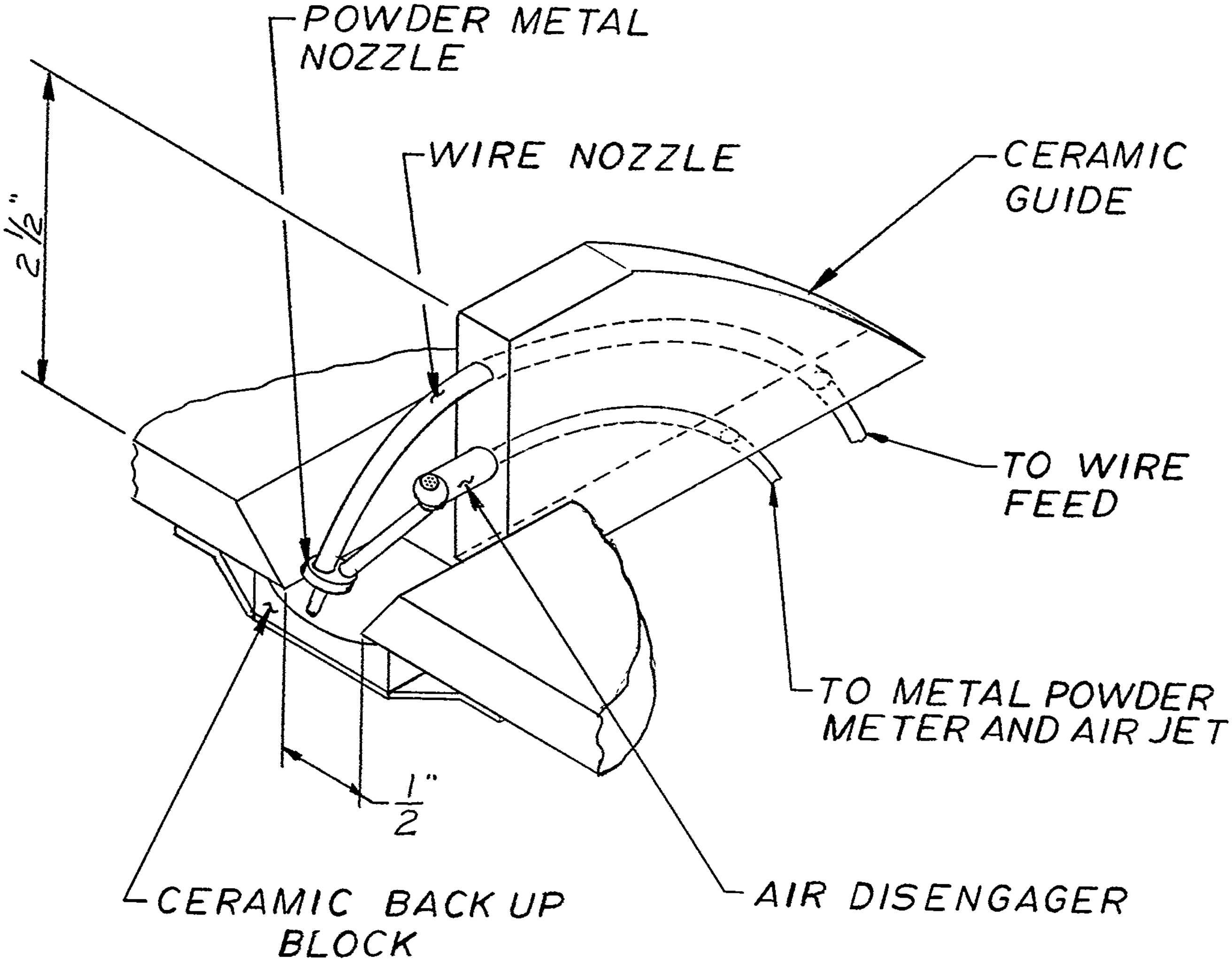

POWDER METAL NOZZLE
WIRE NOZZLE
CERAMIC GUIDE
2½"
TO WIRE FEED
TO METAL POWDER METER AND AIR JET
1/2"
CERAMIC BACK UP BLOCK
AIR DISENGAGER

FIGURE 2

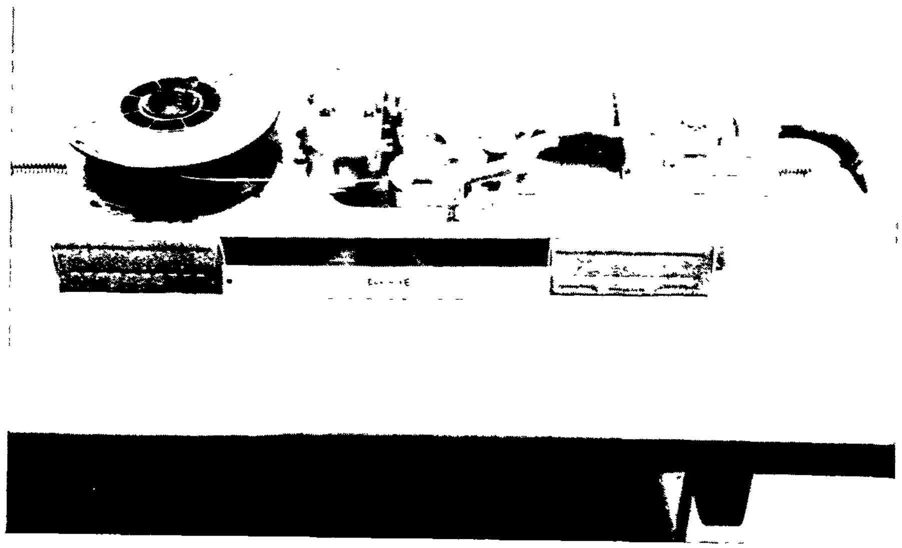


Figure 3. Original One-Side Welding Apparatus.

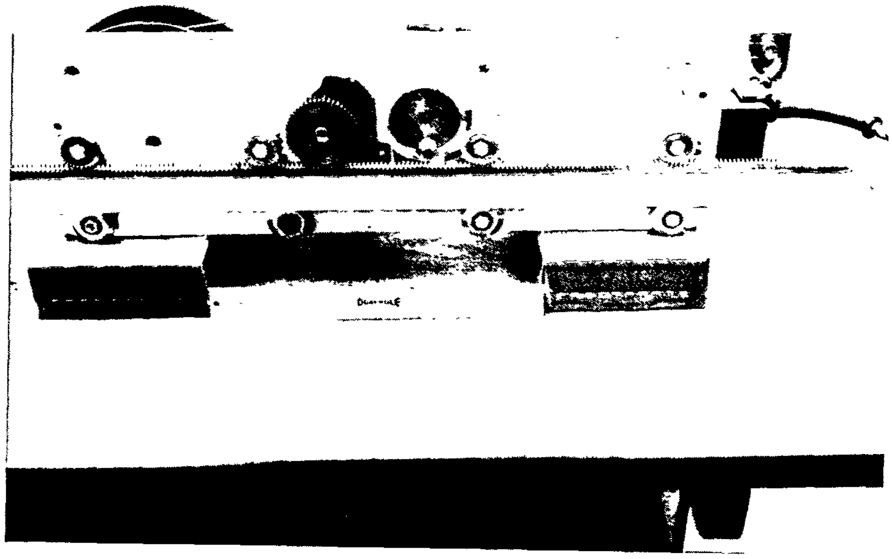


Figure 4. Underside View of One-Side Welding Apparatus.

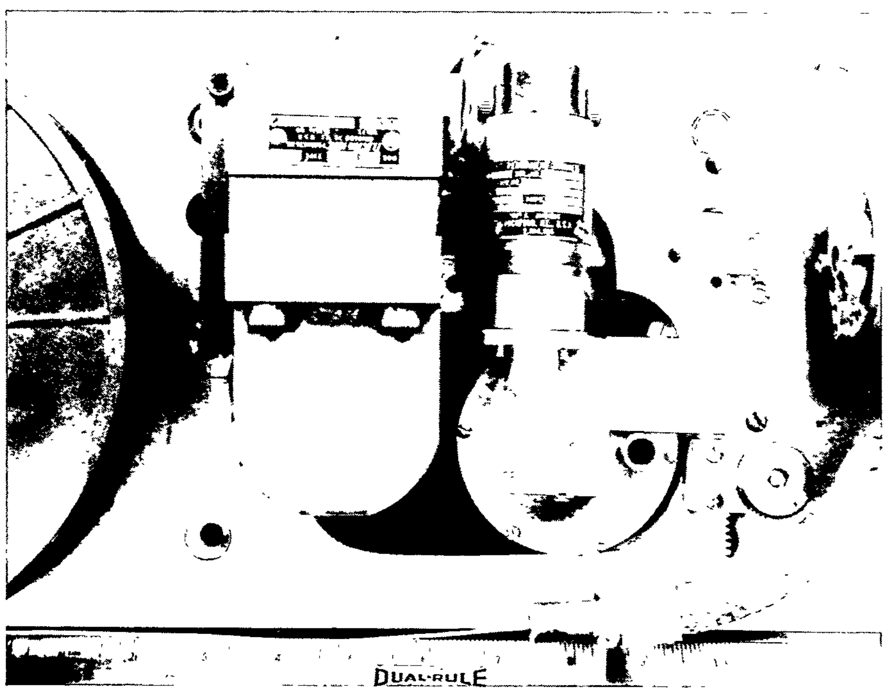


Figure 5. Carriage Drive Motor, Metal Powder Dispensing Device and Positioning Slide.

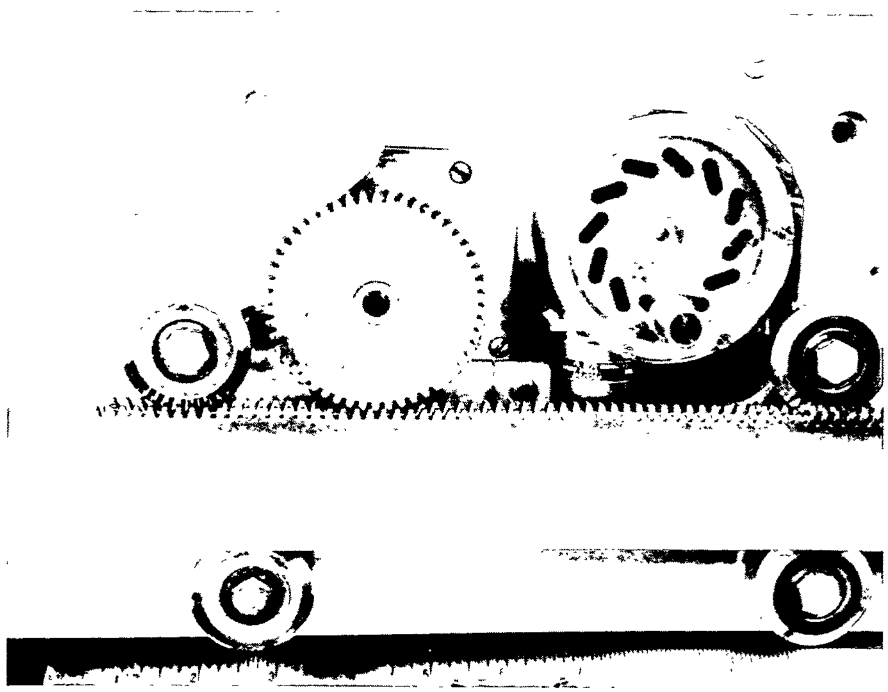


Figure 6. Underside View of Carriage Drive and Metal Powder Dispenser.

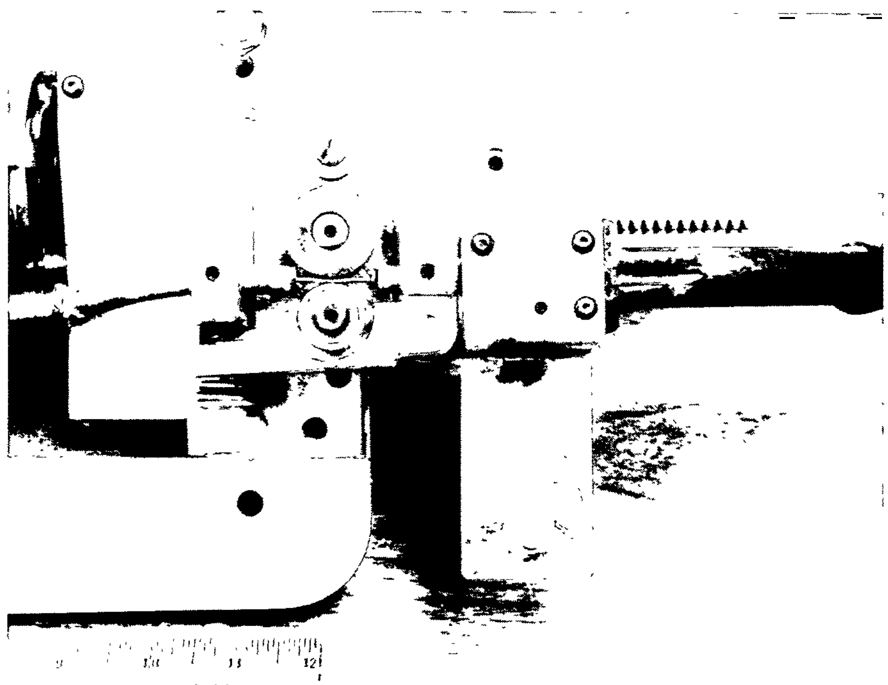


Figure 7. Wire Feed Mechanism and Welding Nozzle.

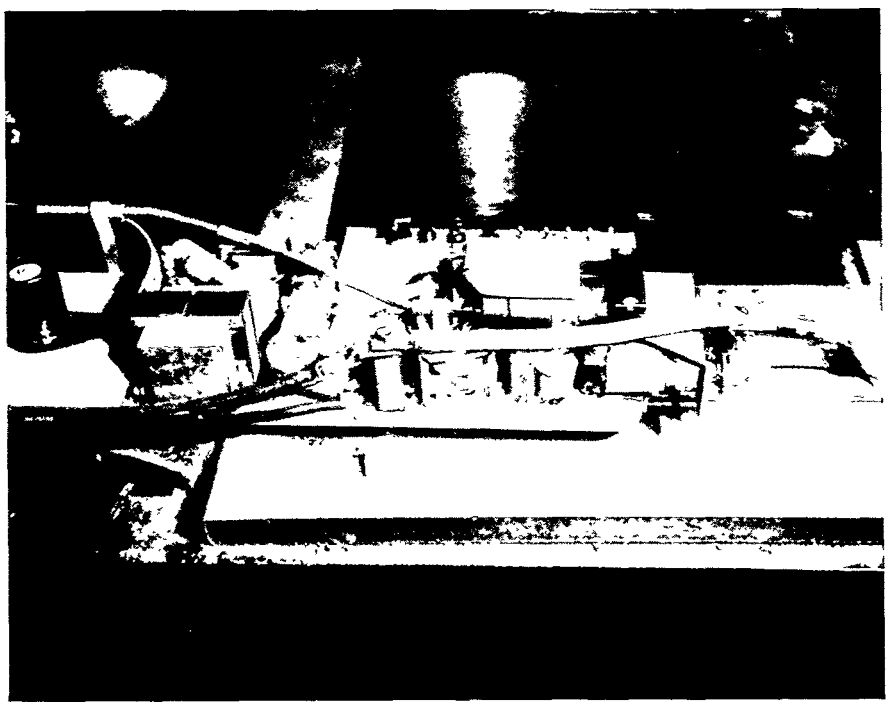


Figure 8. Final One-Side Welding Apparatus.

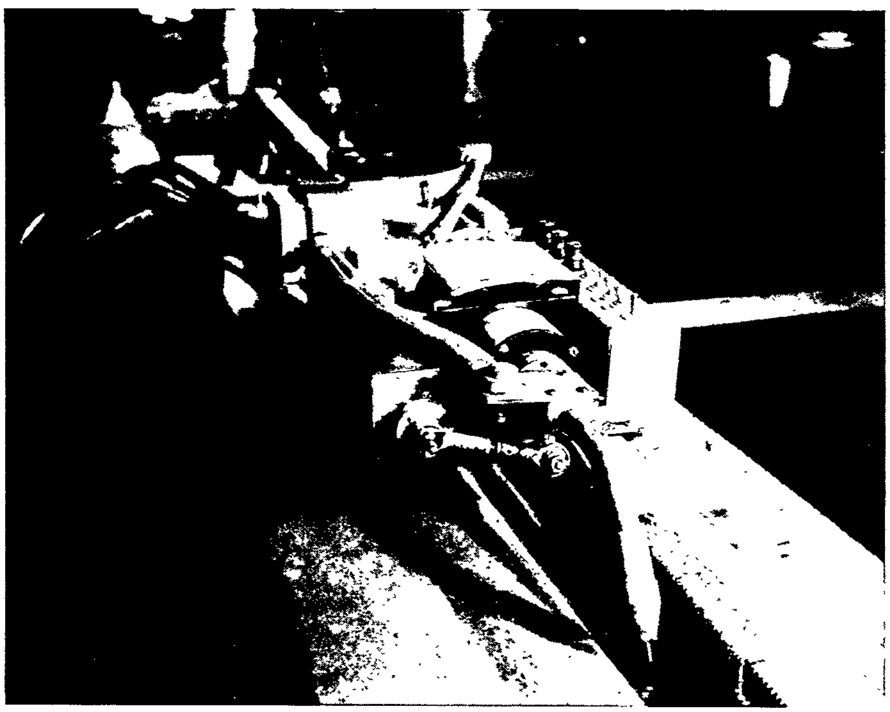
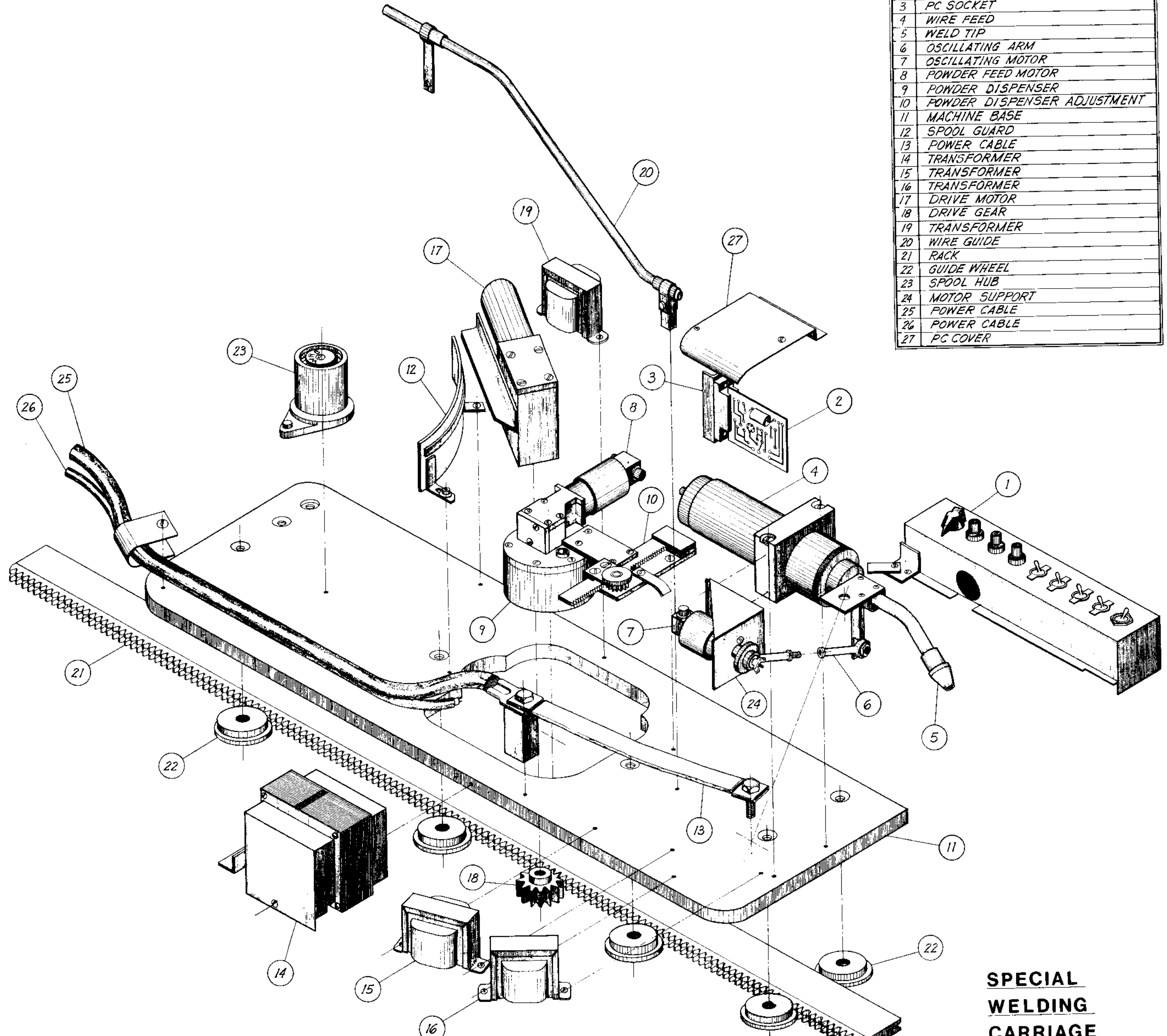


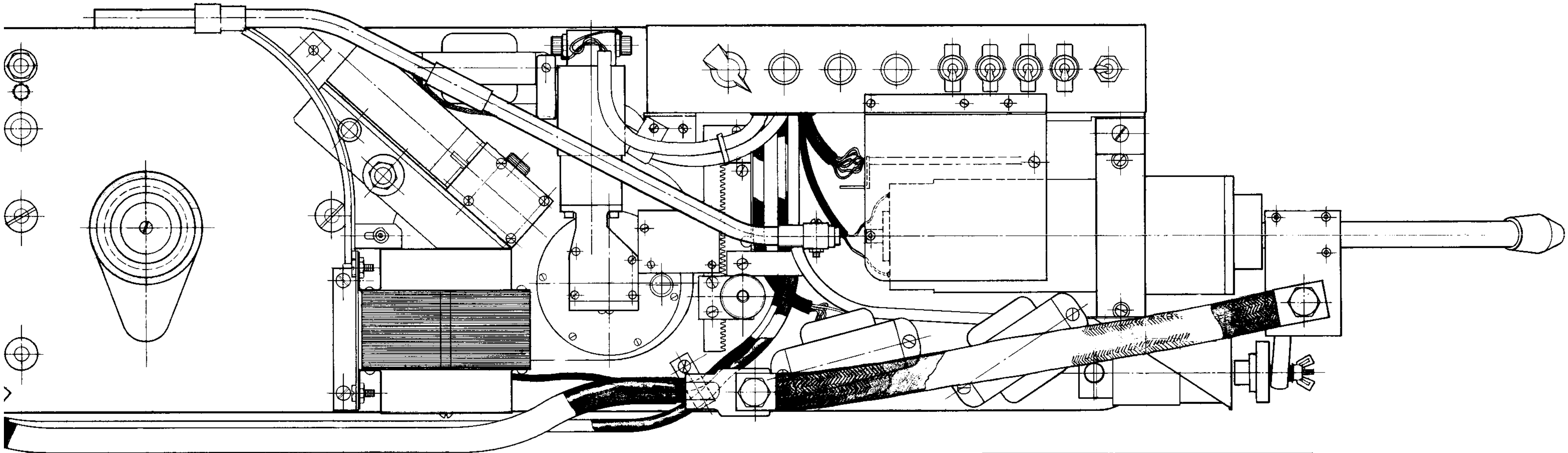
Figure 9. Front View of One-Side Welding Apparatus Showing Weld Nozzle Oscillator.



ITEM	DESCRIPTION
1	ELECTRICAL CONTROLS
2	PC BOARD
3	PC SOCKET
4	WIRE FEED
5	WELD TIP
6	OSCILLATING ARM
7	OSCILLATING MOTOR
8	POWDER FEED MOTOR
9	POWDER DISPENSER
10	POWDER DISPENSER ADJUSTMENT
11	MACHINE BASE
12	SPOOL GUARD
13	POWER CABLE
14	TRANSFORMER
15	TRANSFORMER
16	TRANSFORMER
17	DRIVE MOTOR
18	DRIVE GEAR
19	TRANSFORMER
20	WIRE GUIDE
21	RACK
22	GUIDE WHEEL
23	SPOOL HUB
24	MOTOR SUPPORT
25	POWER CABLE
26	POWER CABLE
27	PC COVER

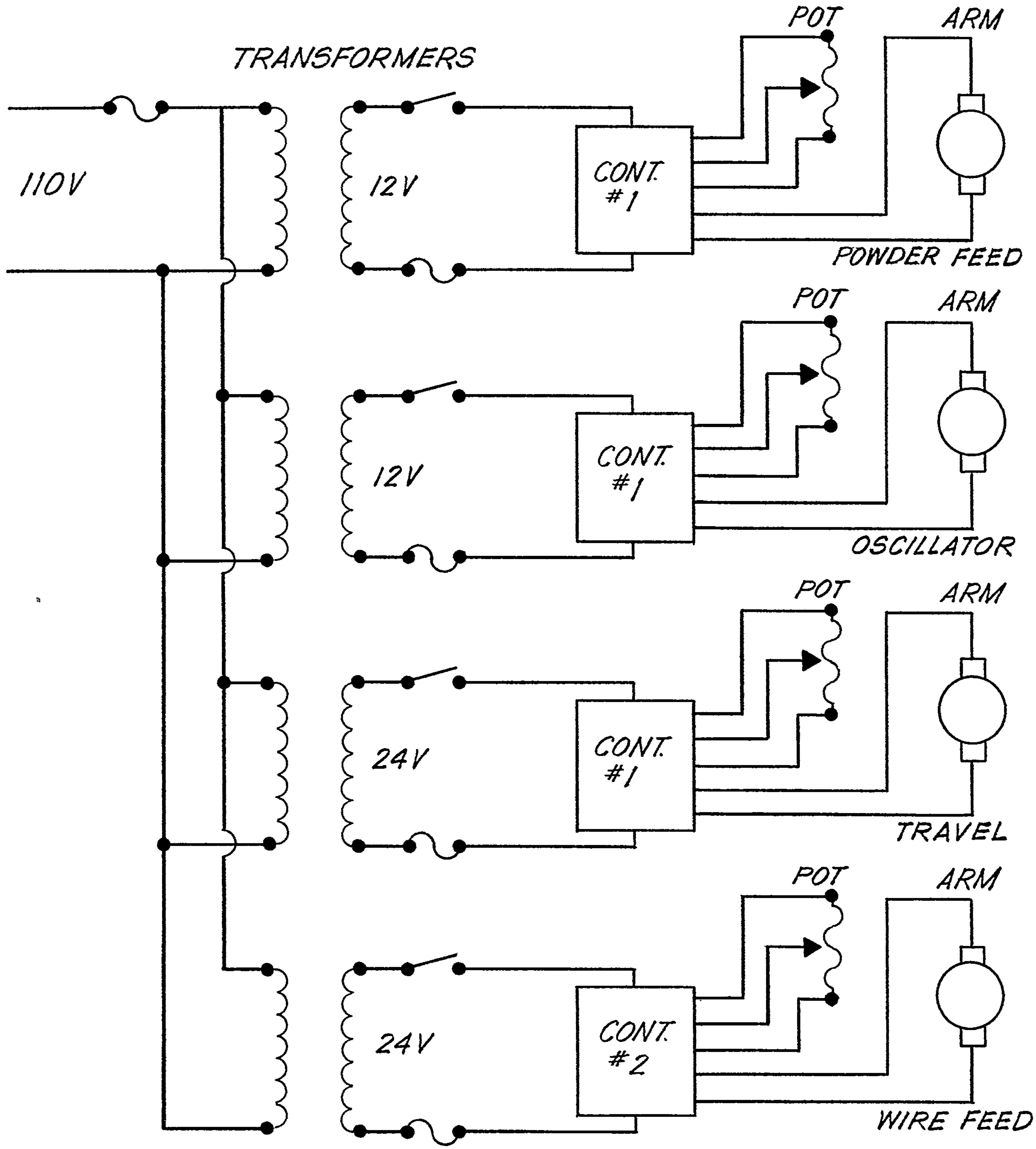
SPECIAL WELDING CARRIAGE

FIGURE 10



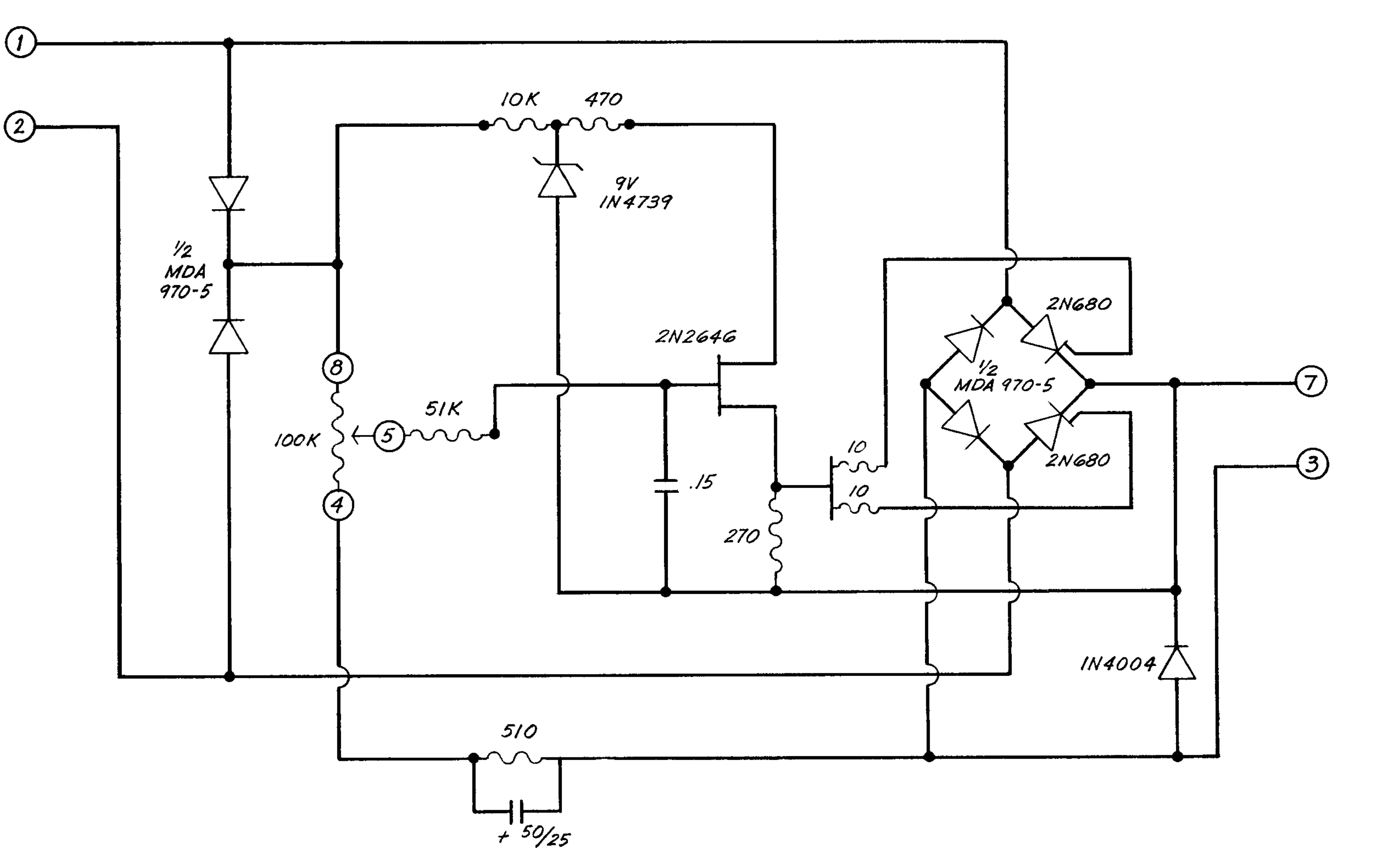
SPECIAL WELDING CARRIAGE

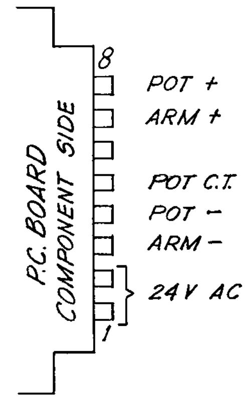
FIGURE 11



CONTROL WIRING

FIGURE 12



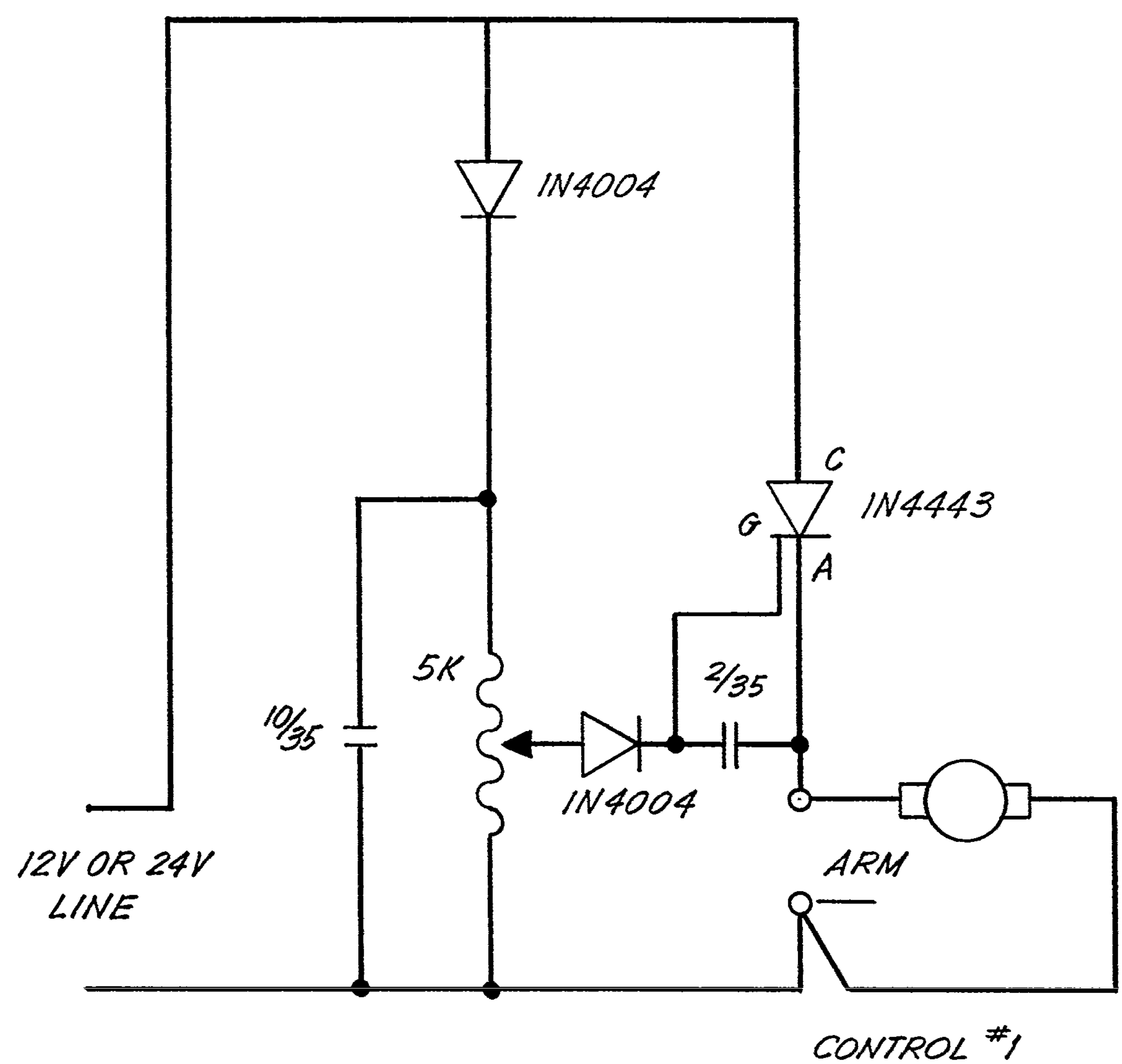


WIRE FEED COLOR CODE

BLACK WHITE	110V
RED GREEN	24V FROM TRS
BLACK RED	ARM
+ RED C+ GREEN − BLACK	POTENTIOMETER

MARAD WIRE FEED SCHEMATIC

FIGURE 13



MARAD CONTROL SCHEMATIC

FOR PERMANENT MAGNET MOTORS

FIGURE 14

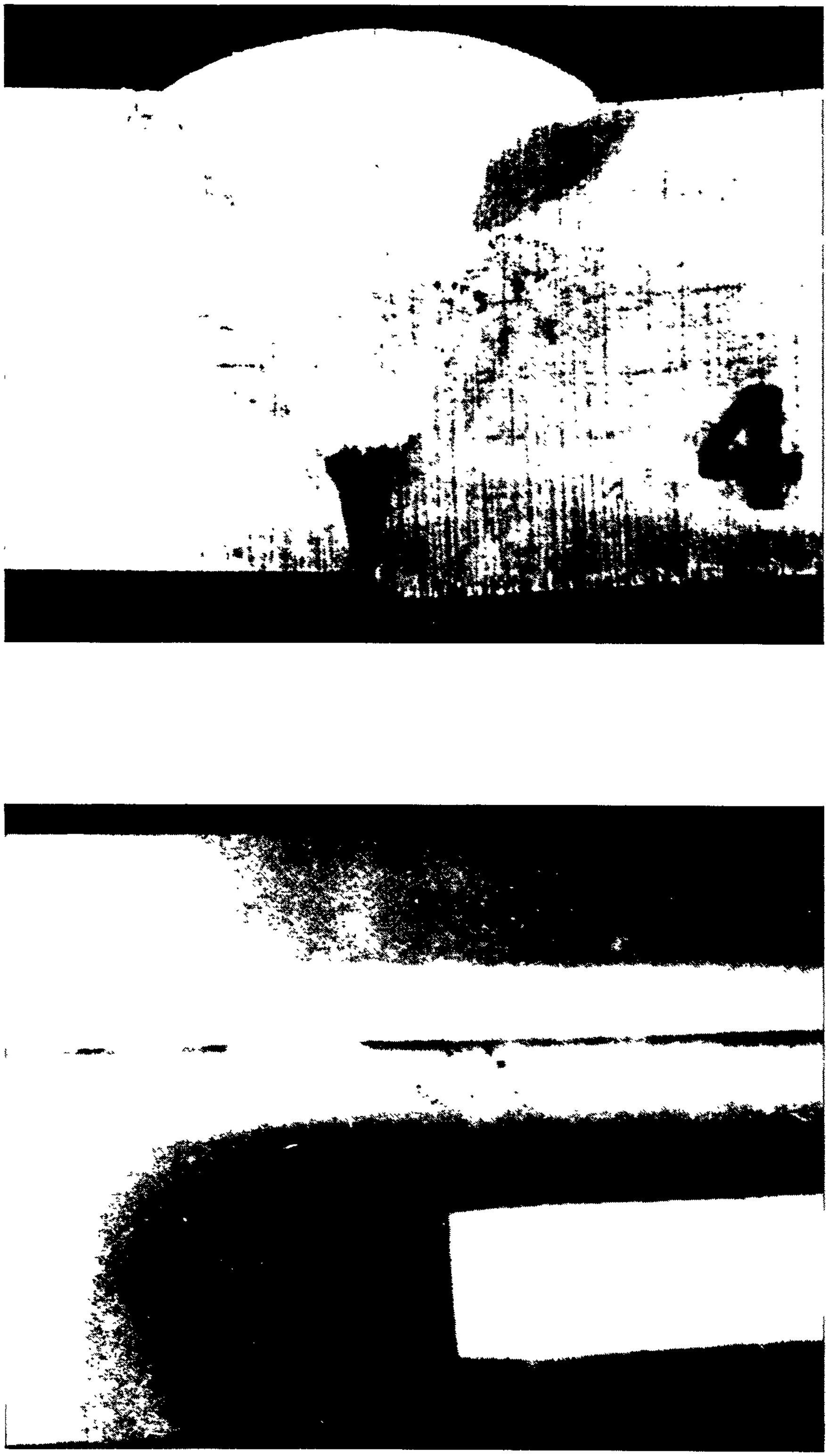


Figure 15. Metallographic Cross Section and Radiograph - Test Plate No. 4 (Tables III and IV)

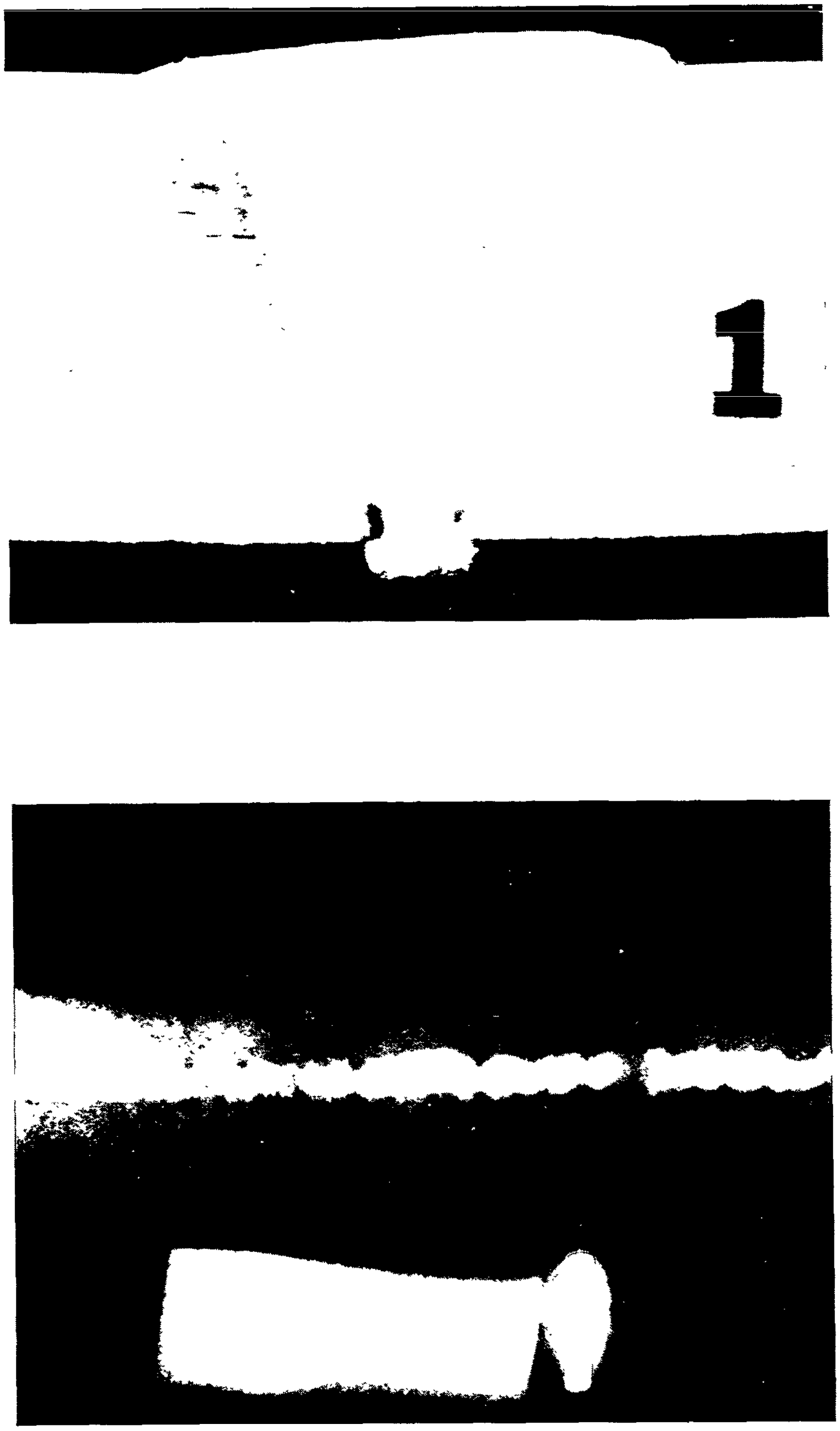


Figure 16. Metallographic Cross Section and Radiograph -

Test Plate No. 1 (Tables III and IV)

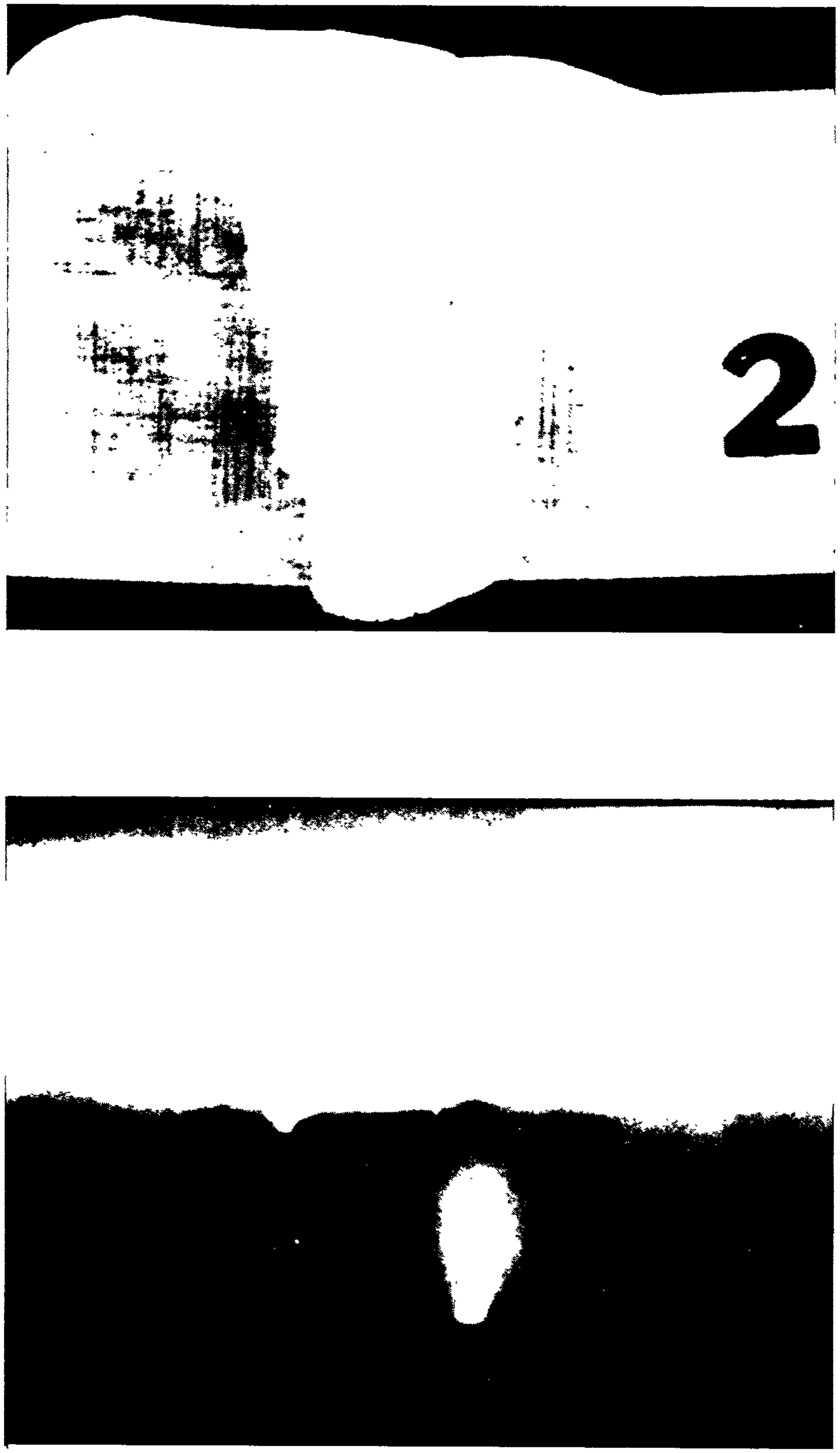


Figure 17. Metallographic Cross Section and Radiograph - Test Plate No. 2 (Tables III and IV)

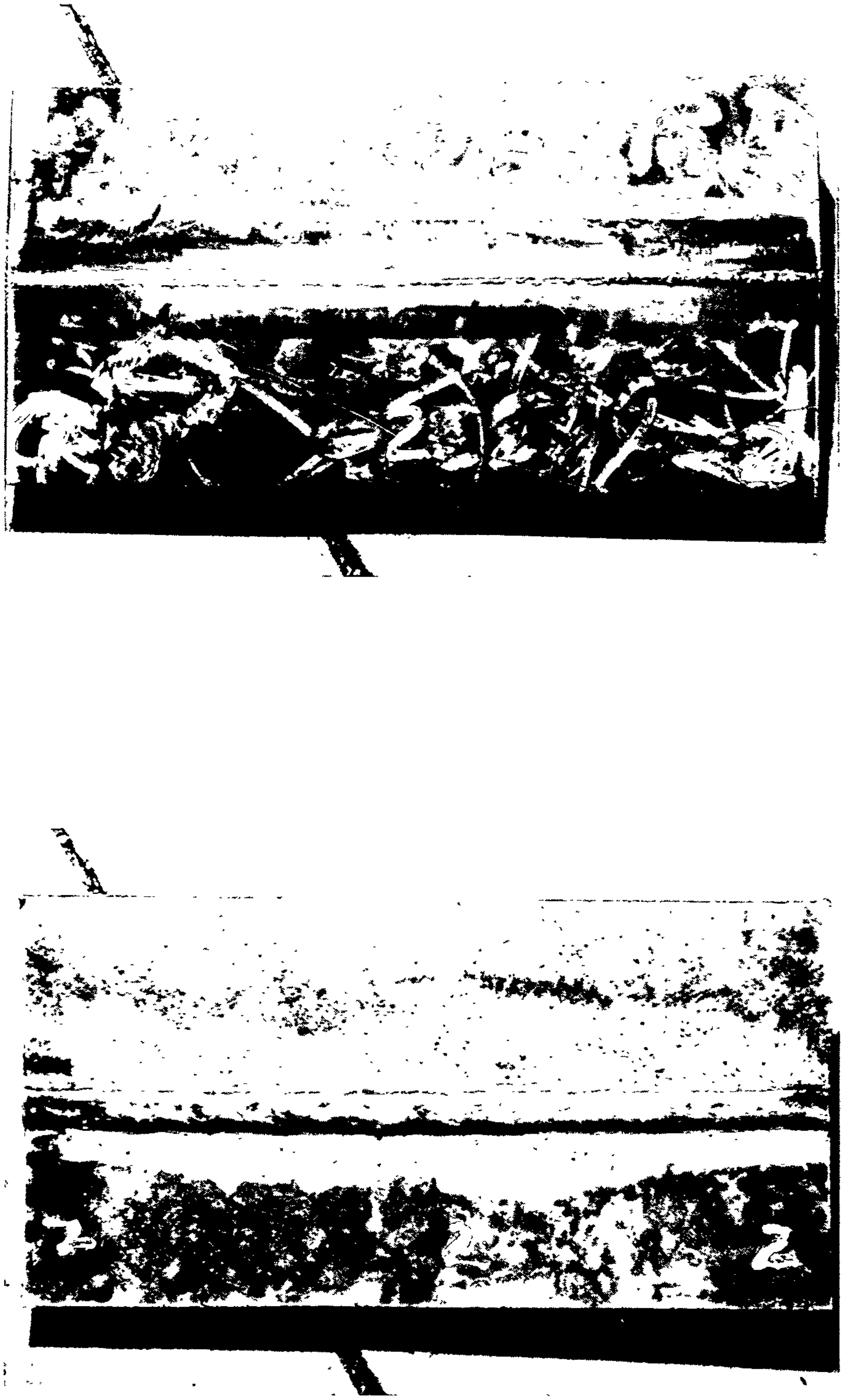


Figure 18. Surface of Test Plate No. 2. On Back Side of Plate, Note "Cold Start" To Right of Figure.

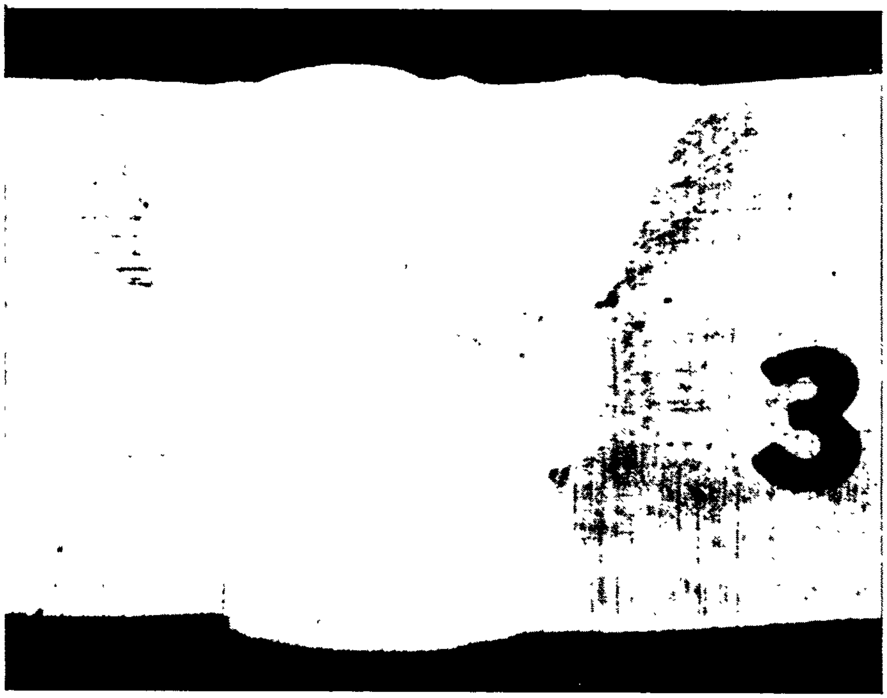


Figure 19. Metallographic Cross Section and Radiograph -

Test Plate No. 3 (Tables III and IV)

Figure 20. Metallographic Cross Section of Weldment Produced With Lincoln NR 302 Electrode and Matching Chemistry Atomized Powder. Test No. 8 (Table VII)

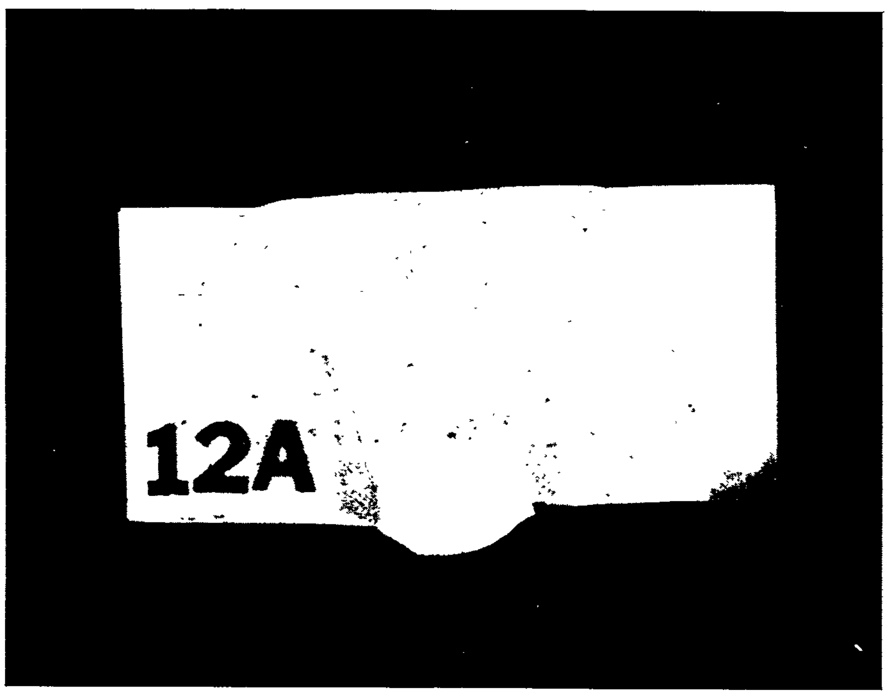


Figure 21. Metallographic Cross Section of Weldment Produced With Lincoln NR 302 Electrode and Blended Mild Steel (M12K) Powder. Test No.12A (Table VII) Note Improved Soundness Relative to Figure 20.

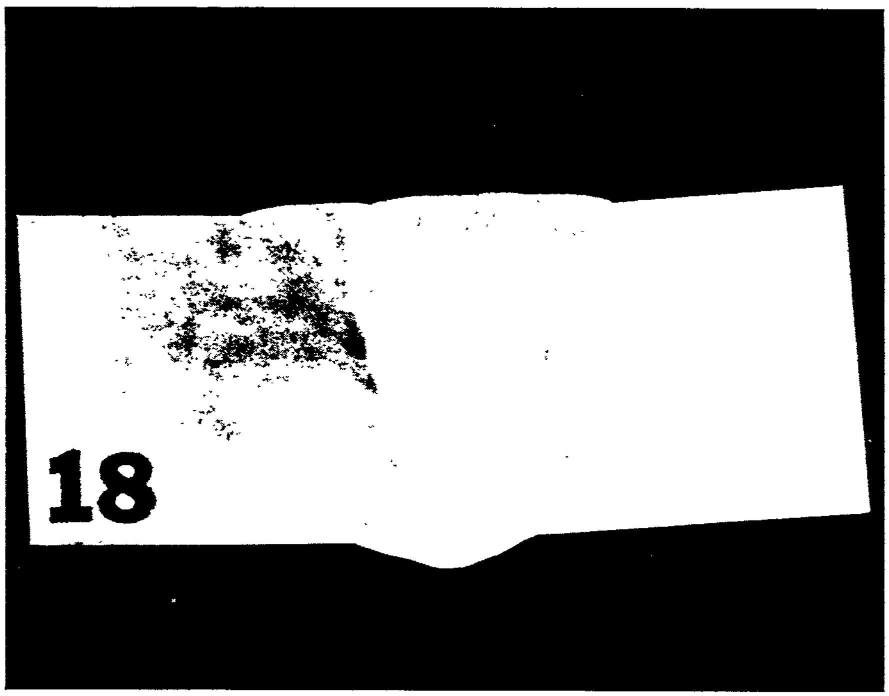


Figure 22. Metallographic Cross Section of Submerged Arc Weldment

(Welding Conditions Given in Table VIII)

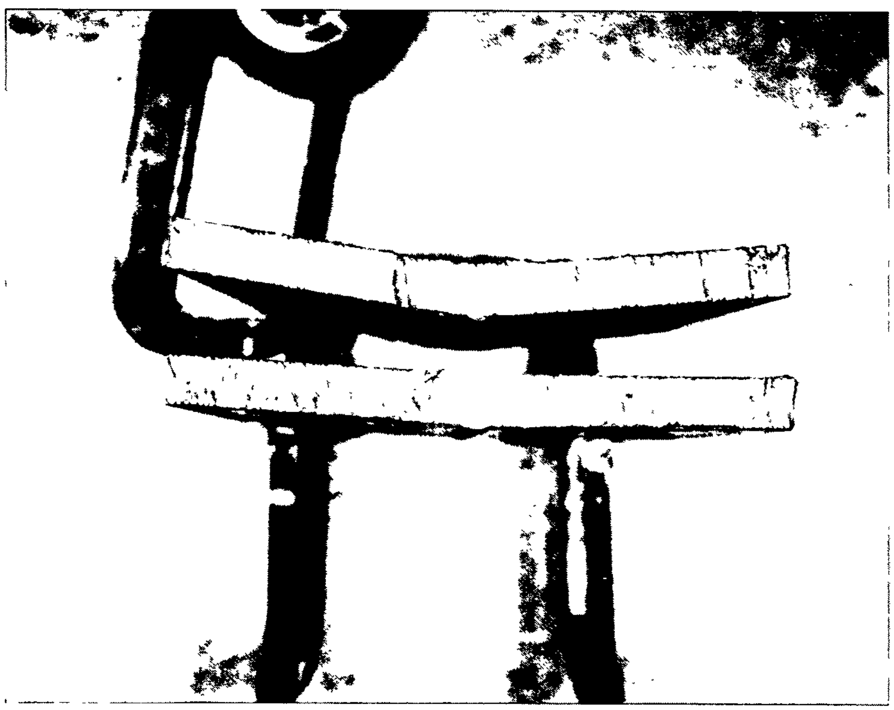


Figure 23. Control of Weldment Distortion With Optimized Welding Procedures (See Text for Description)

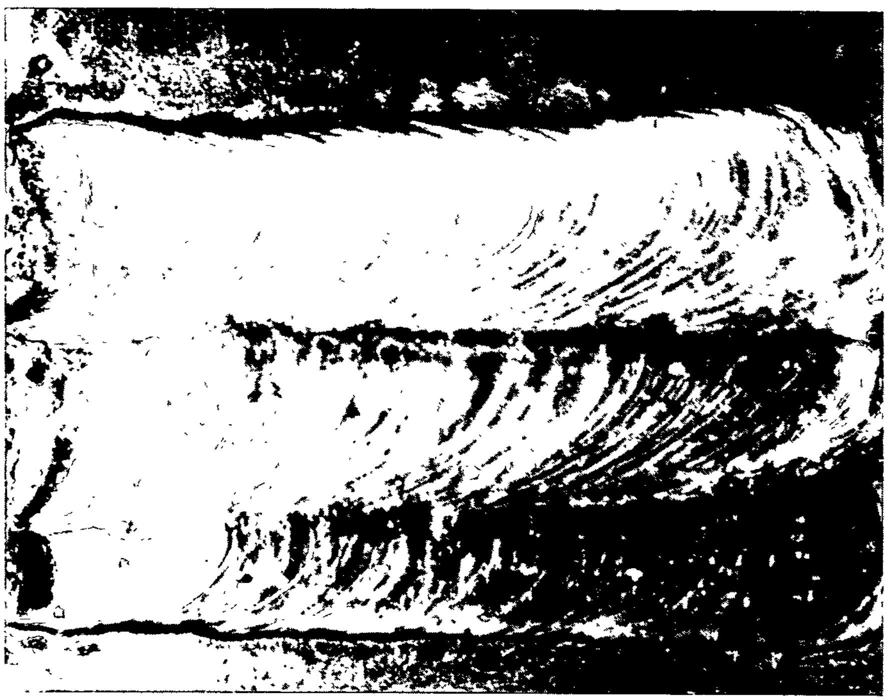


Figure 24. Stainless Steel Cladding Produced With the Experimental Apparatus (Welding Conditions Given in Table X)